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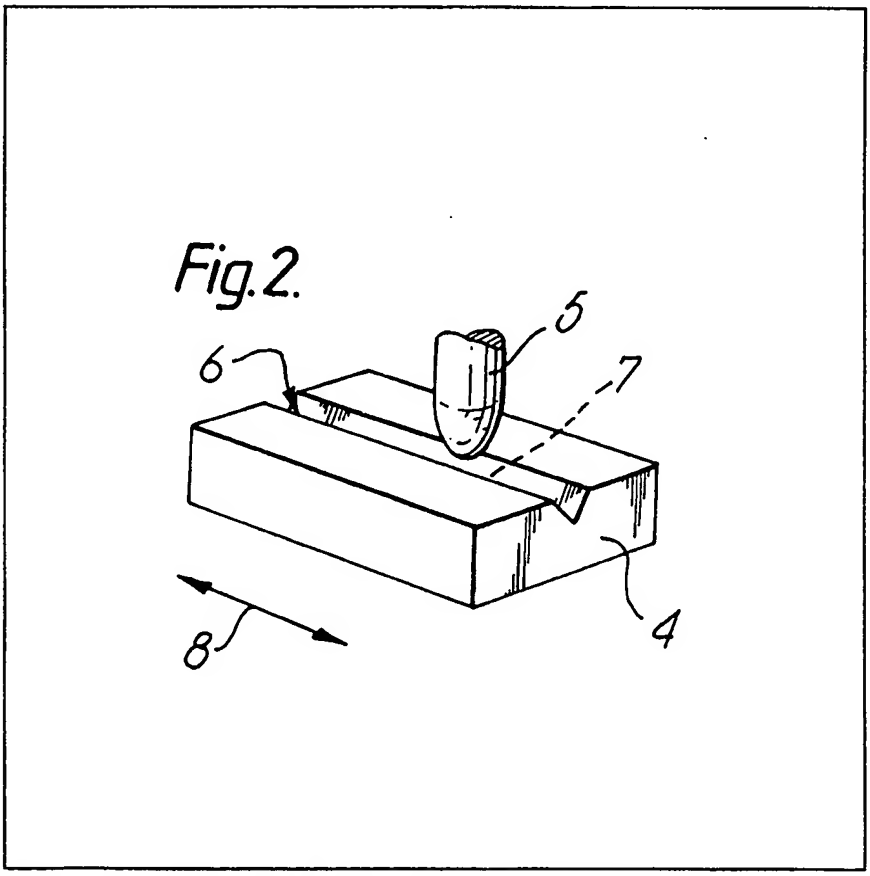
(54) **Optical fibre having lens-shaped end**

(57) It is desirable to be able to provide a lens at the end of an optical fibre to mode-match an asymmetrical optical waveguide or a laser into a symmetrical optical fibre. This may be effected by heating the fibre in an electric arc to soften it and pulling the fibre until it breaks. Then the end may be arc-polished to give the end a suitable profile for a lens.

The thus formed fibre end is then polished into a V-groove (6) in e.g. a glass block (4), which is vibrated lengthwise as indicated by the arrow (8). An abrasive slurry (7) may be placed in the groove to facilitate polishing. Finally the fibre end may be arc-polished to correct its shape.



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig.1a.

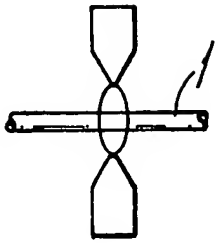


Fig.1b.

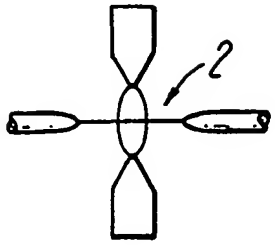


Fig.1c.

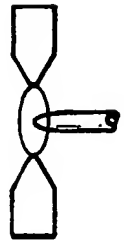


Fig.2.

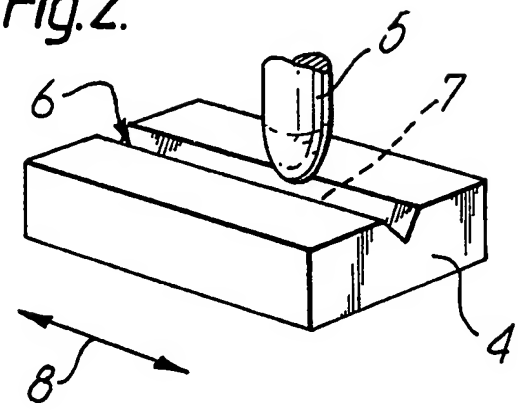


Fig.3a.

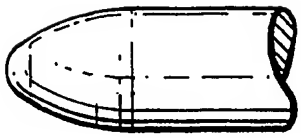


Fig.3b.

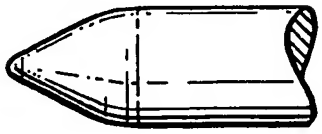


Fig.4a.

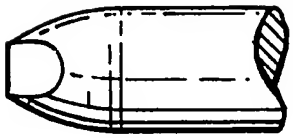


Fig.4b.

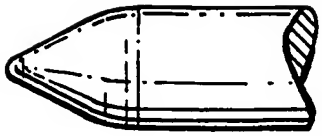
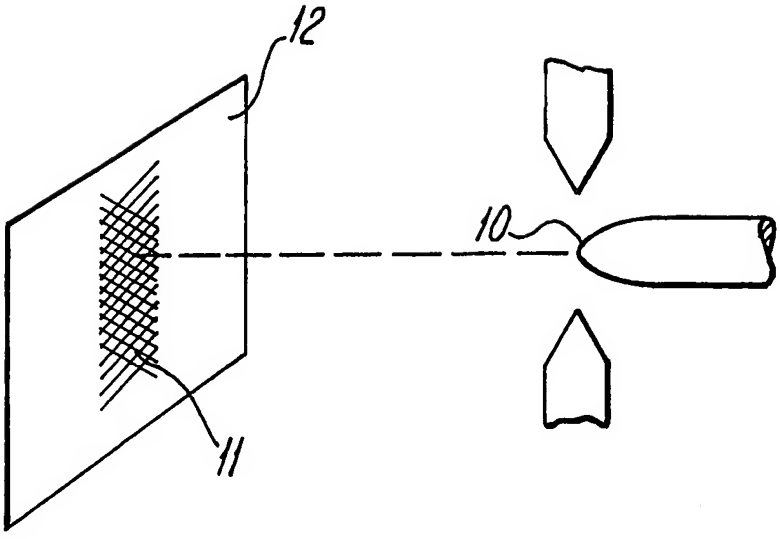


Fig.5.



SPECIFICATION

Optical fibre lens

This invention relates to the production of lenses for coupling light into or from the ends of optical fibres.

It is desirable to provide lenses at the ends of optical fibres to mode-match an asymmetrical high numerical aperture waveguide, or a semiconductor laser into the symmetrical low numerical aperture fibre, i.e. to couple the two devices with high efficiency. Spherical lenses have been produced in the past for single-mode fibre coupling, but are essentially symmetrical and exhibit bad aberration and thus loss. Asymmetrical lenses, such as anastigmatic or anamorphic lenses have been polished directly on fibres, by a laborious process, or formed on roughly-polished fibre ends by dipping into high refractive index glass melts.

An object of this invention is to provide an improved method of making a lens for use with optical fibres, as referred to.

According to the invention there is provided a method of forming an anamorphic or cylindrical lens directly on to the end of an optical fibre, which includes the steps of forming a lens like profile on the end of the fibre and thereafter polishing the profiled end into a vibrating V-groove, the groove being vibrated lengthwise with the fibre end being substantially normal to the length of the groove.

Embodiments of the invention will now be described with reference to the accompanying drawings, in which

Figure 1 shows the various stages in preparing a fibre end for lens formation.

Figure 2 shows the method used to polish a lens on to a fibre end.

Figures 3(a) and *(b)* show the X plane and Y plane shapes of any anamorphic lens formed by the method illustrated in Figures 1 and 2.

Figures 4(a) and *(b)* show the X plane and the Y plane shapes of a cylindrical lens formed by the method illustrated in Figures 1 and 2.

Figure 5 illustrates the technique used to finally adjust lens shape.

In the method to be described, anamorphic or cylindrical lenses are made directly on to the end of an optical fibre by the use of a simple polishing technique which is eminently suited to production. This technique involves polishing a prepared fibre end into a vibrating V-groove, which covers the fibre end to assume a profile defined by the V-groove. To provide the V-groove of the required, very small size, it is formed in glass by a glass drawing technique such as that of our Application No. (T. Bricheno 5). Minor imperfections in the lens profile are corrected by a brief arc fusion stage.

The preparation of the fibre ends is effected as shown in Figure 1, where the fibre 1 is heated by an electric arc as shown in Figure 1 (*a*), when the portion in the arc has been softened, the ends of the fibre are pulled, as in Figure 1 (*b*) to produce a neck 2, and the pulling continued until the ends part. Then one end is further heated in the arc, as indicated in Figure 1 (*c*) to cause a melt back to the desired curvature.

The preliminary formation of a lensed taper on the fibre end ensures accurate self-centering at the polishing stage, which is indicated in Figure 2, where we see a glass V-groove block 4 mode, for instance, by the process of our above-mentioned application. The fibre en 5 is normal to the groove 6, and a cerium oxide slurry is placed in the groove at 7. Then the block is vibrated longitudinally as indicated by the arrow 8.

In the process described, the slurry is cerium oxide, but other materials can be used, e.g. aluminium oxide, titarium dioxide, ferric oxide, and an alkaline silica solution.

If the fibres are polished until the resultant facets just meet, as shown in Figure 3(a) and (b), then a true anamorphic lens results, whereas if the polishing is continued until the facets interset on a line then a cylindrical lens results.

The final adjustment to the lens shape is effected by a discharge surface polishing, see Figure 5, where the lensed end of the fibre is shown at 10 between the arc electrodes. This polishing is effected while observing the far field pattern 1 on a screen 12, the fibre being excited by, for example, a helium-neon laser, which provides a simple and accurate measure of the lens properties.

In the process described above, the initial fusion and lensing stage eases the process since it reduces the amount of material to be removed by polishing and providing a well-centred feature, but is not strictly essential.

A *well* cleared fibre could be polished directly.

CLAIMS

1. A method of forming an anamorphic or cylindrical lens directly on to the end of an optical fibre, which includes the steps of form a lens like profile on the end of the fibre and thereafter polishing the profiled end into a vibrating V-groove, the groove being vibrated lengthwise with the fibre end being substantially normal to the length of the groove.

2. A method of forming an anamorphic or cylindrical lens directly on to the end of an optical fibre, which includes the steps of:

(a) locally heating a length of optical fibre, e.g. by an electrical arc

(b) pulling the fibre to produce a neck in the heated portion and then to part the fibre,

(c) subjecting a parted end of the fibre to further heat to melt the end back until it assumes the profile desired,

(d) polishing the fibre end after preparation by steps (a), (b) and (c), above into a vibrating V-groove, the groove being vibrated lengthwise and the fibre end being substantially normal to the length of the groove.

3. A method as claimed in claim 1 or 2, and in which an abrasive slurry is placed in the groove 6 provides lubricant for the polish.

4. A method as claimed in claim 1, 2 or 3, and in which after the V-groove polishing the lensed end of the fibre is subjected to an arc-discharge profile to produce the wanted lens profile.

5. A method of forming an anamorphic or cylindrical lens directly on to the end of an optical fibre, substantially as described with reference to the accompanying drawing.

6. Apparatus for performing the method of any one of claims 1 to 5.

7. An optical fibre formed with a lens on its end by the method or apparatus of any one of the preceding claims.

New claims or amendments to claims filed on 8 Apr 1982

Superseded claims

New or amended claims

8. Apparatus for forming an anamorphic or cylindrical lens directly on to the end of an optical fibre, which includes:

(a) an electrical arc which is used to heat a region of the optical fibre so as to soften the heated region;

(b) means for pulling the fibre to produce first a nick in the heated region and to thereafter part the fibre;

(c) a heat source adapted to subject a parted end of the fibre to further heat to melt that end back until it assumes the profile desired; and

(d) a vibratory member having a V-groove into which the fibre end which has been prepared by the means set out above is polished, the arrangement being such that the member vibrates in a direction lengthwise of the groove, with the fibre end substantial normal to the length of the groove.

9. Apparatus as claimed in claim 8, and wherein the electrical arc is also used as the heat source referred to as item (c).

10. Apparatus for forming an anamorphic or cylindrical lens directly on to the end of an optical fibre substantially as described with reference to the accompanying drawings.

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